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TITLE:

BATTERY PACK HAVING MEMORY

<u>SPECIFICATION</u>

CROSS-REFERENCE TO RELATED APPLICATIONS

INSA1 The present application is a continuation-in-part of U.S. application Serial No. 08/134,881 (Attorney Docket No. 35717Y) filed October 12, 1993 (now U.S. Pat. No. 5,508,599 issued April 16, 1996), which is a continuation of U.S. application Serial No. 07/769,337 (Attorney Docket No. 35717AAX) filed October 1, 1991 (now U.S. Pat. No. 5,278,487 issued January 11, 1994), which is a continuation of U.S. application Serial No. 07/544,230 (Attorney Docket No. 5717AA) filed June 26, 1990 (now abandoned), which is a division of U.S. application Serial No. 07/422,226 (Attorney Docket No. 5717A) filed October 16, 1989 (now U.S. Pat. No. 4,961,043 issued October 2, 1990), which is a division of U.S. application Serial No. 07/168,352 (Attorney Docket No. 5717Y) filed March 15, 1988 (now U.S. Pat. No. 4,885,523 issued December 5, 1989).

Said application U.S. application Serial No. 07/168,352 is in turn a continuation-in-part of U.S. application Serial No. 06/944,503 (Attorney Docket No. 5717X) filed December 18, 1986 (now U.S. Pat. No. 4,737,702 issued April 12, 1988), which is a continuation-in-part of U.S. application Serial No. 06/876,194 (Attorney Docket No. 5717) filed June 19, 1986 (now U.S. Pat. No. 4,709,202 issued November 24, 1987), which is a division of U.S. application Serial No. 06/797,235 (Attorney Docket No. 5768) filed November 12, 1985 (now U.S. Pat. No. 4,716,354 issued December 29, 1987), which is a continuation-in-part

of U.S. application Serial No. 06/612,588 (Attorney Docket No. 6165) filed May 21, 1984 (now U.S. Pat. No. 4,553,081 issued November 12, 1985), which is a continuation-in-part of U.S. application Serial No. 06/385,830 (Attorney Docket No. 6164) filed June 7, 1982 (now U.S. Pat. No. 4,455,523 issued June 19, 1984).

INCORPORATION BY REFERENCE

The disclosures and drawings of the before mentioned U.S. Pat. Nos. 4,455,523; 4,553,081; 4,709,202; 4,716,354; 4,737,702; 4,885,523; 4,961,043; and 5,278,487 are hereby incorporated herein by reference in their entirety.

The present invention may be utilized as or in conjunction with the battery pack including electronic power saver as described in PCT publication PCT/US90/06383 published May 16, 1991. Said publication PCT/US90/06383 is incorporated herein by reference in its entirety.

The present invention may be utilized as the rechargeable battery of a portable system as described in U.S. Pat. No. 5,363,031 issued November 8, 1994. Said U.S. Pat. No. 5,363,031 is incorporated herein by reference in its entirety.

The present invention may be utilized as the rechargeable battery of a portable system as described in U.S. application Serial No. 07/837,650 (Attorney Docket No. 6599XZ) filed February 18, 1992. Said application Serial No. 07/837,650 is incorporated herein by reference in its entirety.

The present invention may be protected from electrostatic discharge by utilizing the apparatus and method for electrostatic discharge protection as described in U.S. application Serial No. 08/353,778 filed December 12, 1994. Said application 08/353,778 is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention relates to a battery conditioning system for battery means of portable computerized devices, and particularly to a hand-held device including data storage means for storing data pertinent to the battery means of the device, and to a battery conditioning control system including an external charging circuit equipped for communication with data storage means of the hand-held device and/or of the battery means operatively associated with such device. Preferably the control system is capable

of optimizing the performance of a rechargeable electrochemical storage medium while at the same time maximizing its useful life. The invention also relates to control systems generally, and to control systems forming part of hand-held units.

Portable computerized systems are presently being extensively utilized in a wide range of applications. For example, such systems may be utilized in delivery vehicles which are to be away from a central warehouse or the like for a major part of each working day. Recharging operations may take place in locations subject to extremes of temperature. It is particularly crucial to avoid an equipment failure where a portable device is a vital link to the completion of scheduled tasks at remote locations and the like. In such circumstances, a loss of adequate battery power may be just as detrimental as any other malfunction.

Particularly where the battery conditioning control system is to be incorporated in hand-held devices, such control system should be lightweight and compact, and should consume minimum power. For the sake of economy, a microprocessor of a standard design and of minimum complexity is highly desirable.

It is conceived that a particularly advantageous battery conditioning system is achieved where significant portions of the conditioning circuitry are external to the battery operated portable device, and where the portable device contains data storage means which is capable of reliably and flexibly providing information, e.g., to the external circuitry for optimizing battery conditioning operations. Data storage means may be implemented within a battery pack in order to preserve battery characteristics of that particular battery so that unique battery data may be associated with the battery pack. The saved battery pack data may be accessed by a portable battery powered device in which the battery pack is utilized so that charging and discharging routines may be optimized for the particular battery pack.

SUMMARY OF THE INVENTION

It is a basic objective of the present invention to achieve a conditioning system for hand-held battery powered devices providing increased reliability and useful life, and particularly to provide a charging system for hand-held devices wherein charging operation

can be based on the use history and/or other relevant information concerning the specific battery means.

A further object of the present invention is to provide a control system particularly adapted to control battery conditioning of a variety of rechargeable battery means, automatically adaptable to hand-held devices having battery means of different types such as to require different conditioning parameters.

Another object of the invention is to provide a charging current control system for battery powered portable devices which is not only lightweight and compact but which consumes minimum power, and which preferably is adapted to be implemented as an integrated circuit of an economical and simple construction.

An exemplary feature of the invention resides in the provision of a battery conditioning system receptive of different hand-held devices and capable of communication therewith, e.g., to determine the type of conditioning required for respective different internal battery means thereof.

A further feature of the invention relates to a battery conditioning system wherein the system can obtain a relatively accurate indication of the battery energy remaining available for use for one type or a plurality of different types of batteries, and supply the results to a memory means accompanying the battery means during portable operation.

So as to recharge a battery system as rapidly as possible without detriment to an optimum useful life span, battery parameters including battery temperature may be monitored and transmitted to a conditioning system during a charging cycle, and the battery charging current may be adjusted accordingly.

Since a battery may deteriorate when subjected to repeated shallow discharge and recharging cycles, according to the present invention, a count of such shallow charge cycles may be automatically maintained throughout the operating life of the battery system, such that deep discharge cycles may be effected as necessary to maintain desired performance standards.

Furthermore, according to another highly significant feature of the invention, automatically operating battery monitoring and/or conditioning circuitry may be secured with the battery pack for handling as a unit therewith. The monitoring circuitry may receive its

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operating power from the battery pack during storage or handling such that a total history of the battery pack may be retained for example in a volatile memory circuit where such type of memory otherwise provides optimum characteristics for a portable system. The conditioning circuitry may have means for effecting a deep discharge cycle, and concomitantly with the deep discharge cycle, a measure of actual battery capacity may be obtained. From such measured battery capacity and a continuous measurement of battery current during portable operation, a relatively accurate "fuel gauge" function becomes feasible such that the risk of battery failure during field operation may be essentially eliminated. The performance of a given type of battery in actual use may be accurately judged since the battery system can itself maintain a count of accumulated hours of use, and other relevant parameters.

In a simplified system in successful use, the conditioning system is incorporated in the portable utilization device such that the programmed processor of the utilization device may itself automatically effect a deep discharge conditioning cycle and/or a deep discharge capacity test. The deep discharge cycle may be effected at a controlled rate, such that the time for discharge from a fully charged condition to a selected discharge condition may itself represent a measure of battery capacity. Instead of directly measuring battery current during use, the programmed processor may maintain a measure of operating time and/or elapsed time during portable operation, so as to provide an indication of remaining battery capacity. A time measure of operating time may be utilized to automatically determine the time duration of the next charging cycle. When both a main battery and a back-up battery are present, the operating time of each may be individually accumulated, and used to control the time duration of the respective recharging operations.

Additional features of a commercial system in successful use include individual charging and discharging circuits for a main battery and a back-up battery for reliable conditioning of the back-up battery independently of the state of the main battery. Desired parameters such as main battery voltage, ambient temperature (e.g. in the main battery case or in the battery compartment), and charging voltage may be obtained by means of an integrated circuit analog to digital converter, which thus replaces several comparators and many precision costly components of a prior implementation.

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While in an early embodiment, battery charging current was set using a digital to analog converter to establish a set point for an analog current control loop, it is a feature of a further embodiment herein to provide a digital computer for both computing a desired current set point and for modulating current pulses in the battery charging circuit for maintaining a desired average current. Preferably, a computer circuit with a moderate clock rate may determine current pulse modulation steps and control sampling of actual current pulses for purposes of generating a feedback signal. An aliasing type of sampling systematically taken at different phases of the actual current pulse waveform enables use of a particularly low sampling rate.

In a further significant development of the invention, important portions of the conditioning circuitry are external to the battery operated portable device, and yet information specific to a given battery means is retained with the portable device. In an exemplary implementation, a computer operating means of the portable device is programmed and provided with battery information sufficient to select an optimum battery charging rate, for example, e.g., a fast charge or a maintenance charge, and preferably to adjust the charge rate e.g. based on a measure of battery temperature. In a presently preferred system, an external standardized charging circuit has a default condition wherein a charging current is supplied suitable to older types of terminals. Such a charging circuit, however, can be controlled by the computer operating means of preferred types of portable devices so as to override the default charging rate. In this way charging rate may be a function not only of a respective rated battery capacity, but also of other parameters such as battery terminal voltage prior to coupling of the portable device with the charging circuit and/or extent of use of the portable device after a previous charge. In certain applications with high peaks of battery drain, e.g. RF terminals, it is advantageous to avoid a resistance in series with the battery for measuring battery drain during use; an alternate approach measuring operating time in various modes can then be particularly attractive. An advantageous data communication coupling between a portable device computer operating means and a charging circuit may be effected via a data storage register and digital to analog converter. The register may be operated from a battery means while the computer operating means may be in a sleep mode, for example, once the register has received a

suitable computer generated command. The digital analog converter need only be active during a battery charging cycle and can be decoupled from the battery means during portable operation. Such a digital to analog converter is particularly suitable for generating an analog control signal for overriding a default setting of a standardized charging circuit such as described hereinabove.

In a new RF terminal unit, it is conceived that it may be advantageous to make the output of a battery temperature measuring transducer available at an external contact of the terminal so that a low cost charger could supply a charging current taking account of a relatively accurate measure of battery temperature. Further by making temperature transducer (nonzero) output dependent on the presence of charging potential at the terminal, the same temperature sensing line provides an indication as to whether charging potential is present.

In a further embodiment of the present invention, a battery pack having memory may be implemented within the battery pack itself. The duty history of the battery along with present battery data may be stored to be later retrieved by a utilization device. The utilization device may determine present battery conditions in order to relay such information to the operator and may apply appropriate charging algorithms taking into account present battery conditions along with past characteristic charge/discharge behavior in order to optimize future battery charging and discharging. The characteristic behavior exhibited by the battery pack may be stored in an electronic memory system along with other battery pack identifying or tagging information. The battery pack having memory may be assembled using standard battery pack assembly techniques in order to maintain reliability and minimize the costs of the battery pack having memory.

The invention will now be described, by way of example and not by way of limitation, with references to the accompanying sheets of drawings; and other objects, features and advantages of the invention will be apparent from this detailed disclosure and from the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS KLS

FIGS. ~~1 through 17~~ 1-8, 9A-9B, 10-15, 16A-16B and 17 and the brief description thereof are incorporated herein by reference to U.S. Serial. No. 876,194, now U.S. Pat. No. 4,709,202 issued Nov. 24, 1987.

18-19, 20A-20B, and 21-27 KCJ

FIGS. ~~18 through 27~~ and the brief description thereof are incorporated herein by reference to U.S. Serial. No. 07/769,337, now U.S. Pat. No. 5,278,487 issued Jan. 11, 1994.

FIG. 28 depicts the electrical circuit arrangement of an exemplary battery pack having memory.

FIG. 29 shows a physical arrangement of the components of the battery pack having memory in an exemplary manufacture of the invention.

DETAILED DESCRIPTION

1-8, 9A-9B, 10-15, 16A-16B and 17 KCS

The detailed description of FIGS. ~~1 through 17~~ is incorporated herein by reference to the specification at col. 4, line 25, through col. 66, line 4, of the incorporated U.S. Pat. No. 4,709,202.

18-19, 20A-20B, and 21-27 KCS

The detailed description of FIGS. ~~18 through 27~~ is incorporated herein by reference to the specification at col. 5, line 50, through col. 20, line 6, of the incorporated U.S. Pat. No. 5,278,487.

FIG. 28 illustrates the circuit arrangement of an exemplary data pack having memory **28-8**. A number of electrochemical cells **28-2** are arranged in series to provide a predetermined voltage for powering a particular utilization device (not shown). In a preferred embodiment the electrochemical cells **28-2** are nickel-metal hydride cells of the type generally used for portable electronic equipment. Alternatively, the electrochemical cells may be nickel-cadmium cells, lithium-ion cells, or the like. In a preferred embodiment, five cells may be electrically arranged in series resulting in a positive battery voltage terminal **BATT+** and a negative battery voltage terminal **BATT-**.

An electronic memory device **28-4** receives power from the electrochemical cells. The electronic memory device **28-4** is capable of storing information of the particular history of the battery pack **28-8** which may be later retrieved and acted upon accordingly by a utilization device. The electronic memory device **28-4** may store identification information such as manufacturer, date of manufacture, date of sale, serial number, type of electrochemical cells, chain of title from manufacturer to buyer, etc. for tagging and identifying that individual battery pack **28-8**. Such information may be useful for example to trace the origin of defects or to determine the age of the battery pack, for example.

Information as to the actual charging and discharging characteristics of the battery pack **28-8** may also be stored for determining the amount of available capacity remaining in the battery pack **28-8** or for optimizing recharging algorithms. The battery pack **28-8** history may include information such as maximum available capacity, remaining capacity, the total number of charge/discharge cycles the battery pack **28-8** has experienced, the number of charge/discharge cycles since a conditioning cycle, particular charge/discharge characteristics of the battery pack **28-8**, battery temperature, or the like. The actual physical characteristics of the electrochemical cells may thus be monitored and stored in the electronic memory device and retrieved by the utilization device to effectively manage and employ the energy stored in the battery pack **28-8**.

An ideal electronic memory device **28-4** consumes little or no power, is reliable, and is manufactured in a small package. In a preferred embodiment of the invention the electronic memory device **28-4** may be a Dallas Semiconductor DS2434 Battery Identification Chip. The DS2434 is manufactured in a 3 lead TO-92 package having two power leads and a 1-wire data interface lead. The DS2434 has 96 bytes of random access memory (RAM) and 32 bytes of nonvolatile EEPROM memory available for battery storage, includes a digital temperature sensor, and operates at low power. A utilization device may access the battery pack **28-8** data stored in the electronic memory device through the 1-wire interface at communications line **BATT_DATA**.

Operational power of the electronic memory device **28-4** may be supplied by the electrochemical cells **28-2** when the battery pack **28-8** is charged or by an external power source during charging. The nonvolatile memory of the electronic memory device **28-4** allows for retention of stored data in the event that the battery pack **28-8** is completely depleted. The electronic memory device **28-8** may be powered by fewer than the total number of electrochemical cells **28-2** in the battery pack **28-8** when the total series voltage from the entirety of the electrochemical cells **28-2** exceeds the maximum operating voltage of the electronic memory device. In an exemplary embodiment employing five nickel-metal hydride electrochemical cells **28-2** the electronic memory device **28-6** may be powered by three of the electrochemical cells **28-2** by tapping an intermediate voltage point in the

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battery pack **28-8**.

A voltage clamping component 28-4 ~~**28-6**~~ may be utilized to protect the memory device **28-6** from accidental loss of stored memory states due to electrostatic discharge. For example an operator may touch communications terminal **BATT_DATA** during installation of the battery pack **28-8** into a utilization device and inadvertently apply an electrostatic discharge through the communications terminal **BATT_DATA** to the electronic memory device **28-4** thereby destroying the stored memory states and causing a loss of the stored battery pack **28-8** data. The voltage clamping component **28-6** may be an AVX Transguard type component connected between communications line **BATT_DATA** and negative terminal **BATT-** of the battery pack **28-8** which is typically a ground reference. The voltage clamping component **28-6** clamps any high voltage transient occurring at the **BATT_DATA** terminal in order to prevent damage to the electronic memory device **28-4**.

FIG. 29 depicts a physical configuration of the battery pack **29-8** as manufactured. The battery pack **29-8** may be assembled using the process normally employed to assemble rechargeable battery packs wherein thin metal straps **29-10** are spot welded to the electrochemical cells **29-2** to interconnect the electrochemical cells **29-2**. Using standard battery pack assembly techniques provides reliable low impedance and low cost connections within the battery pack **29-8**. No circuit board nor any other components which may increase manufacture costs and reduce the reliability of the connections are needed to assemble the battery pack **29-8**.

Communications line **BATT_DATA** requires a large area contact pad as shown in FIG. 29 for optimum signal integrity. The straps **29-10** may be comprised of individual pieces of metal an maybe placed on an insulating substrate to hold them in the proper orientation for assembly. Metal pieces **29-10** may be formed by chemical etching from a single sheet of material which may consist of a traditional flexible circuit or an equivalent thereof.

The spot welding process may be a possible source of damage to the electronic memory device **29-4** due to the application of a potentially damaging high voltage on the pins of the electronic memory device **29-4** by the spot welder. The potentially damaging

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effects of spot welding to the electronic memory device **29-4** may be mitigated or eliminated by assembling the voltage clamping **29-6** device to the battery pack **29-8** assembly prior to attaching the electronic memory device. The electronic memory device **29-4** and the voltage clamping component **29-6** may be affixed to metal conductors **29-10** using a traditional electrical connection technique such as soldering before the spot weld is applied. Once the electronic component **29-4** and the voltage clamping device **29-6** are affixed to metal conductors **29-10**, metal conductors **29-10** may be mechanically clamped to a low electrical potential point such that no damaging voltage will be applied to the pins of the electronic memory device.

In view of the above detailed description of a preferred embodiment and modifications thereof, various other modifications will now become apparent to those skilled in the art. The claims below encompass the disclosed embodiments and all the reasonable modifications and variations without departing from the spirit and scope of the invention.